

What is claimed is:

1. A plasma generator for space charge neutralization of an ion beam, comprising:

an ion implantation system operable to generate an ion beam and direct the ion beam along a beamline path;

5 an electric field generation system operable to generate an electric field in a portion of the beamline path, the electric field having a portion oriented in a first direction;

10 a magnetic field generation system operable to generate a magnetic field in the portion of the beamline path, the magnetic field having a portion oriented in a second direction that is perpendicular to the first direction; and

15 a gas source operable to introduce a gas in a region occupied by the electric field and the magnetic field, wherein electrons in the region move in the region due to the electric field and the magnetic field, and wherein at least some of the electrons collide with the gas in the region to ionize a portion of the gas, thereby generating a plasma in the region associated with the portion of the beamline path.

2. The plasma generator of claim 1, wherein the electric field generation system comprises one or more pairs of electrodes coupled to an RF power source, thereby generating an alternating electric field between the electrodes in the region.

20 3. The plasma generator of claim 2, wherein the one or more pairs of electrodes comprise interdigitated electrodes.

25 4. The plasma generator of claim 2, wherein each of the one or more pairs of electrodes have opposing sides, a top face, and a bottom face, respectively, and wherein the opposing sides and the bottom face of the one or more pairs of

electrodes are surrounded by a dielectric material, and wherein the alternating electric field between the electrodes extends from the top faces thereof.

5 5. The plasma generator of claim 4, further comprising a quartz layer overlying the top faces of the one or more pairs of electrodes.

6. The plasma generator of claim 1, wherein the portion of the beamline path comprises a mass analysis system.

10 7. The plasma generator of claim 6, wherein the mass analysis system further comprises a pair of coils having a beamline path disposed therebetween, wherein the coils are operable to generate a magnetic field substantially perpendicular to a propagation direction of the ribbon ion beam when current conducts therethrough, and wherein the pair of coils comprises the magnetic field generation system.

15 8. The system of claim 7, wherein the electric field generation system comprises a pair of biased electrodes operable to generate the electric field therebetween.

20 9. The system of claim 8, wherein the electric field generation system further comprises an RF source coupled to the pair of biased electrodes.

25 10. The system of claim 8, wherein the pair of coils extend in a width direction of the ribbon ion beam and define first and second opposing side portions of the mass analysis system on either end of the coils, and wherein the pair of electrodes reside on the first side portion.

11. The system of claim 10, wherein each of the pair of biased electrodes comprises an arcuate conductive segment generally following a contour of the mass analysis system and a plurality of conductive members electrically coupled and concatenated along the arcuate conductive member.

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12. The system of claim 11, wherein the plurality of conductive members further comprise magnets, wherein each of the magnets has a north pole associated with a first end and a south pole associated with a second end thereof.

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13. The system of claim 12, wherein magnets on one of the conductive segments are arranged so that the north and south poles are arranged in a first orientation, wherein a north pole of a magnet faces inwardly toward a magnet on the other of the conductive segments, and a south pole faces outwardly away from the magnet on the other conductive segment, and magnets on the other of the conductive segments are arranged in a second orientation, wherein a north pole of a magnet faces inwardly toward the magnet on the one conductive segment, and a south pole faces outwardly away from the magnet on the one conductive segment.

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14. The system of claim 12, wherein magnets on one of the conductive segments are arranged so that the north and south poles are arranged in a first orientation, wherein a south pole of a magnet faces inwardly toward a magnet on the other of the conductive segments, and a north pole faces outwardly away from the magnet on the other conductive segment, and magnets on the other of the conductive segments are arranged in a second orientation, wherein a south pole of a magnet faces inwardly toward the magnet on the one conductive segment, and a north pole faces outwardly away from the magnet on the one conductive segment.

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15. The system of claim 12, wherein the magnets are operable to generate multi-cusp fields along the first side portion of the mass analysis system, and wherein the multi-cusp fields are operable to interact with the electric field to move electrons in a region local thereto, and wherein at least some of the moving electrons are 5 operable to ionize a gas therein, thereby generating the plasma.

16. The system of claim 15, further comprising a plurality of magnets extending along the beamline path on a second side portion of the mass analysis system opposite the arcuate conductive segments on the first side portion, and each 10 having north and south poles associated therewith, wherein the plurality of magnets are oriented approximately ninety degrees with respect to the magnets on the arcuate conductive segments and operable to generate multi-cusp magnetic fields along the second side portion of the mass analysis system.

15 17. The plasma generator of claim 1, wherein the portion of the beamline path comprises a drift region downstream of a mass analysis system, wherein the plasma in the beamline path portion provides space charge neutralization for the ion beam passing therethrough.

20 18. The plasma generator of claim 1, wherein the ion implantation system comprises an ion source operable to generate a ribbon ion beam.

25 19. The plasma generator of claim 1, wherein the ion implantation system comprises a scanning system operable to scan a beam for creating a ribbon-like ion beam.

20. An ion implantation system, comprising:
an ion source operable to generate an ion beam;
a mass analysis system operable to receive the ion beam and deflect ions
within the beam having a desired charge-to-mass ratio along a predetermined path,
5 the mass analysis system further comprising a plasma generator operable to
generate plasma therein for neutralization of space charge associated with the ion
beam, wherein the plasma generator comprises:

10 an electric field generation system operable to generate an electric field
in the mass analysis system, the electric field having a portion oriented in a first
direction;

15 a magnetic field generation system operable to generate a magnetic
field in the mass analysis system, the magnetic field having a portion oriented in a
second direction that is perpendicular to the first direction, wherein electrons therein
move due to the electric field and the magnetic field, and wherein at least some of the
electrons collide with residual gas therein to ionize a portion of the gas; and

an end station downstream of the mass analysis system, operable to support a
workpiece for implantation thereof *via* the ion beam.

21. The system of claim 20, wherein the electric field generation system
20 comprises one or more pairs of electrodes coupled to an RF power source, thereby
generating an alternating electric field between the electrodes in the region.

22. The system of claim 21, wherein the one or more pairs of electrodes
comprise interdigitated electrodes.

25 23. The system of claim 21, wherein each of the one or more pairs of
electrodes have opposing sides, a top face, and a bottom face, respectively, and

wherein the opposing sides and the bottom face of the one or more pairs of electrodes are surrounded by a dielectric material, and wherein the alternating electric field between the electrodes extends from the top faces thereof.

5 24. The system of claim 23, further comprising a quartz layer overlying the top faces of the one or more pairs of electrodes.

10 25. The system of claim 20, wherein the ion beam comprises a ribbon-shaped ion beam.

15 26. The system of claim 25, wherein the mass analysis system further comprises a pair of coils having a beamline path disposed therebetween, wherein the coils are operable to generate a magnetic field substantially perpendicular to a propagation direction of the ribbon ion beam when current conducts therethrough.

20 27. The system of claim 26, wherein the pair of coils comprises the magnetic field generation system.

25 28. The system of claim 26, wherein the electric field generation system comprises a pair of biased electrodes operable to generate the electric field therebetween.

25 29. The system of claim 28, wherein the electric field generation system further comprises an RF source coupled to the pair of biased electrodes.

30. The system of claim 28, wherein the pair of coils extend in a width direction of the ribbon ion beam and define first and second opposing side portions of

the mass analysis system on either end of the coils, and wherein the pair of electrodes reside on the first side portion.

31. The system of claim 30, wherein each of the pair of biased electrodes comprises an arcuate conductive segment generally following a contour of the mass analysis system and a plurality of conductive members electrically coupled and concatenated along the arcuate conductive member.

32. The system of claim 31, wherein the electric field generation system further comprises an RF source coupled to the arcuate conductive members, thereby generating an RF electric field between the conductive members residing on one of the arcuate conductive segments and the conductive members on the other of the arcuate conductive segments, respectively, and wherein a direction of the RF electric field is generally perpendicular to a magnetic field within the beamline path.

33. The system of claim 31, wherein the plurality of conductive members further comprise magnets, wherein each of the magnets has a north pole associated with a first end and a south pole associated with a second end thereof.

34. The system of claim 33, wherein magnets on one of the conductive segments are arranged so that the north and south poles are arranged in a first orientation, wherein a north pole of a magnet faces inwardly toward a magnet on the other of the conductive segments, and a south pole faces outwardly away from the magnet on the other conductive segment, and magnets on the other of the conductive segments are arranged in a second orientation, wherein a north pole of a magnet faces inwardly toward the magnet on the one conductive segment, and a south pole faces outwardly away from the magnet on the one conductive segment.

35. The system of claim 33, wherein magnets on one of the conductive segments are arranged so that the north and south poles are arranged in a first orientation, wherein a south pole of a magnet faces inwardly toward a magnet on the other of the conductive segments, and a north pole faces outwardly away from the magnet on the other conductive segment, and magnets on the other of the conductive segments are arranged in a second orientation, wherein a south pole of a magnet faces inwardly toward the magnet on the one conductive segment, and a north pole faces outwardly away from the magnet on the one conductive segment.

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36. The system of claim 33, wherein the magnets are operable to generate multi-cusp fields along the first side portion of the mass analysis system, and wherein the multi-cusp fields are operable to interact with the electric field to move electrons in a region local thereto, and wherein at least some of the moving electrons are operable to ionize a gas therein, thereby generating the plasma.

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37. The system of claim 36, further comprising a plurality of magnets extending along the beamline path on a second side portion of the mass analysis system opposite the arcuate conductive segments on the first side portion, and each having north and south poles associated therewith, wherein the plurality of magnets are oriented approximately ninety degrees with respect to the magnets on the arcuate conductive segments and operable to generate multi-cusp magnetic fields along the second side portion of the mass analysis system.

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38. A method of generating a plasma in an ion implantation system, comprising:
generating an electric field and a magnetic field having a portion generally

perpendicular to a portion of the electric field in a region to move electrons within the region; and

5 providing a gas in the region, wherein at least some of the moving electrons collide with portions of the gas to ionize the gas, thereby generating the plasma in the region.

39. The method of claim 38, wherein generating the generally perpendicular electric and magnetic field comprises:

10 placing a pair of electrodes in a mass analysis guide having a magnetic field oriented generally perpendicular to a direction of propagation of an ion beam in the ion implantation system; and

15 biasing the pair of electrodes, thereby generating the electric field therebetween, wherein the pair of electrodes are positioned such that a direction of the resultant electric field is generally perpendicular to the magnetic field in the mass analysis system.

40. The method of claim 39, wherein generating the generally perpendicular electric and magnetic field comprises:

20 configuring a plurality of conductive magnet members along two conductive, electrically isolated segments, wherein each of the conductive magnet members have a north pole and a south pole associated therewith, wherein the magnet members are operable to generate multi-cusp magnetic fields therebetween; and

25 biasing the plurality of conductive magnetic members on one segment and the plurality of conductive members on the other segment, thereby generating an electric field therebetween.

41. The method of claim 40, wherein the plasma is generated in a mass analysis system within the ion implantation system, and the mass analysis system comprises an arcuate passageway having first and second opposing sides extending along the arcuate passageway, and wherein the two conductive, electrically isolated segments extend along a first side spaced apart from one another.

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42. The method of claim 41, wherein the conductive magnetic members associated with one conductive segment are configured to extend along the arcuate passageway, wherein a south pole of each member faces outwardly away from center portion of the arcuate passageway, and a north pole of each member faces inwardly toward the center portion of the arcuate passageway.

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43. The method of claim 42, wherein the conductive magnetic members associated with the other conductive segment are configured to extend along the arcuate passageway, wherein a south pole of each member faces outwardly away from a center portion of the arcuate passageway, and a north pole of each member faces inwardly toward the center portion of the arcuate passageway.

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44. The method of claim 38, wherein generating the electric field comprises:

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configuring a pair of interdigitated electrodes along a beamline path of the ion implantation system; and
biasing the pair of interdigitated electrodes to generate the electric field therebetween.

45. The method of claim 44, wherein the pair of interdigitated electrodes are located within a mass analysis system, and wherein the interdigitated electrodes

are configured to generate the electric field therebetween having an orientation generally perpendicular to a magnetic field within the mass analysis system employed for deflecting an ion beam propagating therethrough.

5 46. The method of claim 45, wherein the mass analysis system comprises an arcuate passageway having first and second opposing sides, and wherein the interdigitated electrodes are located on one of the first and second opposing sides.

10 47. The method of claim 38, wherein providing a gas comprises employing any residual gas within the region.